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EFFECTS OF FUEL MANAGEMENT TREATMENTS IN PINON-JUNIPER VEGETATION AT A SITE ON THE COLORADO PLATEAU

04-1A-11222048-163

Effects of Fuel Management Treatments in Piñon-Juniper Vegetation at a Site on the Colorado Plateau

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Joint Fire Science Project Number 03-3-3-58
Final Report
9/28/2006

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Suggested Citation: Brooks, M.L., C. Deuser, J.R. Matchett, H. Smith, and H. Bastian. 2006. Effects of Fuel Management Treatments in Piñon Juniper Vegetation at a Site on the Colorado Plateau. JFSP Project Number 03-3-3-58, Final Report. Delivered to the Joint Fire Science Program, National Interagency Fire Center, 3833 S. Development Ave., Boise, ID 83705-5354, 28 September. 21 pages.

EXECUTIVE SUMMARY

Piñon-juniper woodlands have expanded beyond their historical range in the Western United States, due partly to land management practices such as fire suppression that began with settlement of the region in the late 1800s. This woodland expansion has replaced sagebrush steppe vegetation, leading to degraded wildlife habitat, depleted soil seedbanks, reduced plant species diversity, and increased potential for soil erosion and high intensity crown fire. In an attempt to restore historical conditions, "post-settlement" trees that established after the late 1800s have been removed to free resources for sagebrush steppe vegetation to become re-established. Chain saw and chemical thinning methods have gradually replaced chaining as the primary thinning tool, in some cases followed by seeding native understory plants and/or

burning. Unfortunately, the cost-effectiveness and ecological effects of various combinations of thinning, seeding, and burning remain mostly unknown, making it difficult for land managers to develop effective management plans. The need for this information is greater now than ever, because of recent plans to apply large-scale fuel treatments across the Western United States, a region dominated by sagebrush-steppe and piñon-juniper vegetation.

This project was designed as the first of two phases at a site on the western Colorado Plateau dominated by Utah juniper (*Juniperus osteosperma*) and two-needle piñon pine (*Pinus edulis*). Phase 1 focused on comparing the cost effectiveness of different types of thinning treatments targeting 80% of the post-settlement juniper and piñon pine trees: two chain saw treatments (cut; cut, limb, scatter) and one herbicide treatment (15% Tordon 22K applied at the base of the tree). The cut treatment was evaluated alone and when combined with seeding of the native understory grass species bottlebrush squirreltail (*Elymus elymoides*) at 3 pounds per acre and blue grama (*Bouteloua gracilis*) at 2 pounds per acre. The second phase, pending additional funding beyond the scope of the current project, will add fire as a treatment and compare fire behavior among previous thinning treatments, and vegetation response during the immediate postfire years.

The results of the current study are still preliminary, but a few items can be reported at this time. The percent reduction of post-settlement juniper density varied from 68% to 92% among thinning treatments, and the reduction of post-settlement piñon pine density varied 64% to 77% among treatments. Thus, implementation of the treatments resulted in actual thinnings that varied somewhat above and below the target of 80%. The cost of each treatment also varied, but to a much greater degree: $400/acre (cut), $500/acre (cut, limb, scatter), and $70/acre (herbicide). Tree thinning resulted in significant increases in shrub density, forb cover, plant species richness, and surface fuel cover within the first 2 post-treatment years. In general, all three thinning methods produced similar results after 2 years. Results are still pending on the thinning plus seeding experiment, and they will be delivered to the JFSP at a later date.

Our preliminary results indicate that similar effects on understory vegetation and fuelbed characteristics can be achieved during the first 2 post-treatment years by using any one of the three methods tested. The one exception is the coarse woody fuel load which is significantly higher in the two chain saw treatments compared to the herbicide and control treatments. These results suggest that the least expensive method (herbicide) may be preferable, at least in the short-term. However, we do not know at this time what the longer-term effects may be, and plans are in place to monitor these plots to document future changes. We also have plans for a follow-up study to address the objectives of phase 2 of this project.

INTRODUCTION

Woodlands dominated by piñon pine (*Pinus* spp.) and juniper (*Juniperus* spp.) occupy broad regions within western North America (West 1999). Since Anglo-American settlement of this region during the late 1800s, the range of piñon-juniper woodlands have expanded significantly (Miller et al. 1999, 2000). The establishment of "post-settlement" trees in new areas has been associated with increased fire return intervals due partly to fire suppression and the reduction of surface fuels caused by the introduction of livestock grazing (Miller and Rose 1999). This woodland expansion has replaced shrub steppe vegetation, leading to increased amounts of hazardous woody fuels in wildland urban interface (WUI) and other areas, degradation of wildlife habitat otherwise provided by sagebrush-steppe vegetation, decreased species diversity, loss of soil seedbanks, decreased aquifer recharge, and increased soil erosion

rates (Koniak and Everett 1982, Wilcox and Breshears 1994, Davenport et al. 1998, West, 1999, Miller et al. 2000).

As sagebrush-steppe has converted to piñon-juniper woodlands, fire regimes have shifted from moderate intensity, moderate return interval (~50 years), surface fires, to high intensity, long return interval (>100 years), crown fires. Changes in vegetation composition, fuel structure, and fire regime are generally characterized as shifts in fire regime condition class (FRCC), from historical, pre-settlement or otherwise "natural" conditions (FRCC1), to moderate (FRCC2) and high (FRCC3) departures from historical conditions (Hann and Bunnell 2001).

In FRCC2 stands where invading woodlands are relatively young, having established since the middle of the 1900s, tree cover is low and comprised of younger age class 1 and 2 post-settlement trees (Bradshaw and Reveal, 1943), and cover and seedbank densities of shrubs, grasses, and forbs are likely to be similar to the adjacent shrub steppe vegetation. These stands tend to be on the deeper soils of the lower slopes of hillsides and mountains. These open woodlands possess surface fuels that may still carry low to moderate intensity surface to passive crown fires. These early successional invading woodlands are generally classified as FRCC2 landscapes, deviating slightly from historic natural fuel and fire regimes characteristics. The potential is relatively high for FRCC2 areas to recover back to their pre-invasion state following piñon-juniper thinning without active revegetation of sagebrush-steppe species.

In FRCC3 stands where invading woodlands are relatively old and are comprised of young and moderate age class 1 through 3 post-settlement trees (Bradshaw and Reveal, 1943), having established after the late 1800s, tree cover is high, whereas cover and seedbank densities of shrubs, grasses, and herbs are low, differing significantly from adjacent shrub-steppe vegetation. These stands tend to be on the shallower soils of the middle slopes of hillsides and mountains. Many federal fire managers have reported that fire does not easily propagate in these closed-canopy stands easily except under extreme fire weather conditions, which typically results in intense crown fires that endanger rural communities and may have undesirable effects on soils and plants. The potential may be relatively low for FRCC3 landscapes to recover to their pre-invasion conditions following woodland thinning without active revegetation of sagebrush-steppe species.

Various thinning treatments have been used to reduce density and cover of piñon and juniper, and ultimately shift FRCC2 and FRCC3 woodlands to historical FRCC1 shrub-steppe landscapes, but their effects have been poorly documented and are difficult to predict. Results have not been reported widely and a complete analysis accounting for multiple management activities have not been researched extensively. This lack of predictability makes many land managers wary of embarking on expensive thinning projects that could potentially have undesirable side effects. The existing information void also complicates the environmental review and approval process and can stall fuels reduction projects in the planning phase. Prudent land management requires that expensive, broad-scale, landscape manipulations should be studied and evaluated first to identify the best prescription to approach the problem, before obligating significant resources to treatments that may do more environmental harm than good. Thus, there is a significant management need across the Western United States for fuel management prescriptions that can effectively restore FRCC1 fuel and fire regime characteristics, while producing minimal negative ecological side-effects.

One of the primary concerns about thinning treatments is that they cause significant amounts of disturbance, which may promote the dominance of invasive non-native plants such as cheatgrass (*Bromus tectorum*) (Brooks and Pyke 2001). In some cases, invasive non-natives

create new fuel conditions and alter fire regimes (D'Antonio and Vitousek 1992, Brooks et al. 2004). Cheatgrass is present in the piñon-juniper/sagebrush steppe ecotone, and is especially prevalent in disturbed areas. There is a very real concern that efforts to restore FRCC2 and FRCC3 woodlands to FRCC1 shrub-steppe may increase cheatgrass dominance, promote recurrent fire, and push landscapes into FRCC2 and FRCC3 invasive non-native annual grasslands.

OBJECTIVES

Phase 1

(current proposal)

Thinning Experiment

- Compare the cost effectiveness among commonly used chain saw and herbicide thinning treatments for reducing density and cover of piñon and juniper trees.
- Evaluate the effects of thinning treatments on cover, soil seedbank density, and plant species diversity.
- Evaluate the effects of thinning treatments on fuelbed characteristics.

Thinning and Seeding Experiment

- Evaluate the effects of thinning followed by seeding on cover, soil seedbank density, and plant species diversity.
- Evaluate the effects of thinning followed by seeding on fuelbed characteristics.

Phase 2

(future proposal pending additional funding)

- Evaluate the effects of thinning treatments on fire behavior.
- Evaluate the effects of thinning treatments followed by fire on cover, soil seedbank density, and plant species diversity.

METHODS

Study Site

The study area is located within a single watershed on the northern rim of the Grand Canyon of the western Colorado Plateau in the State of Arizona. The administrative boundaries of the project are within the Lake Mead National Recreation Area portion of the Grand Canyon–Parashant National Monument, an area jointly managed between the Bureau of Land Management and National Park Service. The site is at 1,890 m (6,200 ft) with slopes from 2-15%. Mean annual precipitation is 33 to 43 cm (13 to 17 in), bimodally distributed in summer monsoons from late June to early September, and winter frontal systems from November through March. Mean annual soil temperature is 27 to 31 °C (81 to 88 °F), and the frost-free period is 135 to 150 days.

The Natural Resource Conservation Service conducted an Order Three-Soil Survey for the site in 1999, which indicated the soils are a well-drained, gravelly loam (35-55% clay) with a pH of 7.2 from the surface (A1 0 to 1 inch) and a pH of 6.6 from 3 to 15 cm (1 to 6 in) below the

surface. The soil parent material is limestone with depth to bedrock ranging from 48 to 152 cm (19 to 60 in). Chert gravel covers 50 to 70% of the soil surface. The potential plant community composition includes an understory of >50% native perennial grasses, although current perennial grass cover is much lower.

Based on pre-treatment brush belt transects installed in 2002 by an NPS-Fire Monitoring Handbook (FMH) crew, we are able to describe pre-treatment plant community characteristics at the study site. Dominant woody perennials include Utah juniper *(Juniperus osteosperma)* (1,864/ha), two-needle piñon pine *(Pinus edulis)* (1,792/ha) big sagebrush *(Artemisia tridentata var. tridentata)* (1,337/ha), cliff rose *(Purshia mexicana)* (1,204/ha), broom snakeweed *(Guterrezia satrothrae)* (432/ha), Palmer's oak *(Quercus turbinella)* (392/ha. Pre-treatment dominance of herbaceous species was difficult to determine because sampling was done after a few drought years, but species that were observed included in descending order of relative cover were sulfur flower *(Eriogonum umbellatum)*, red brome *(Bromus madritensis* ssp. *rubens)*, squirreltail *(Elymus elymoides)*, cheatgrass *(Bromus tectorum)*, and blue grama *(Bouteloua gracilis)*. Thus, the study site can be generally characterized as an FRCC2 stand of piñon and juniper with a moderate understory component.

European settlement of the site occurred during the late 1800's, which introduced cattle grazing that continued until the late 1980's when grazing was ceased and a cattle exclosure fenceline was constructed along the boundary line between NPS and BLM lands just to the north of the project area. Historic evidence of cattle grazing remains in the study region including corrals, drift fences, and earthen water tanks. Some of this region was chained in the late 1950's to early 1960's by a local rancher to try and improve range forage conditions.

Fire suppression has likely occurred concomitantly with European settlement and organized fire fighting responsibilities have been shared by the BLM and NPS since the 1950's. A Prescribed Natural Fire Plan was implemented for the area in 1998 and fires are currently being managed as "wildland fire for resource benefits" which is synonymous for managing naturally caused fires to burn under certain management prescribed conditions.

Lightning storms commonly occur in the area throughout the monsoon season. There is historical evidence of moderately-sized fires up to 100 acres in area, but in the last 25 years smaller fires less than 1 acre and single tree fires have been more common. The NPS has implemented over 6,000 acres of prescribed fires in the area since approval of the program which started in 1994. These burned acres occurred in ponderosa pine forest, sagebrush-steppe, and piñon-juniper woodland vegetation types. In piñon-juniper woodlands, prescribed burn objectives were only met in the old-chained areas. Most of the unchained area did not carry fire, even when a helitorch was used under extreme fire weather conditions. Effectiveness monitoring has shown that plant diversity has generally increased in previously burned areas, however native grasses have only increased in small isolated areas, possibly due to a previously depleted soil seedbank. The need for understanding both short-term and long-term effects of alternative treatments besides simply re-introducing fire is necessary to understand which management tools should be used to meet resource objectives for most of the piñon-juniper woodlands in this region.

Current management goals at this site are to conserve, restore, and maintain naturally functioning ecosystems and cultural resources. Other goals are to maximize native plant and animal diversity within their natural range of variation. A primary management concern is related to soil conservation, and it is believed that current site conditions will not adequately sustain soil resources. There is also concern that closed woodlands will reduce habitat quality for

wildlife and increase the potential for high intensity crown fire which may lead to slow recovery of native plants and increased dominance of invasive non-native plants. The site is ideal to conduct restoration activities because cattle grazing is currently excluded, no elk exist in the area, and deer, small mammals, and insects are the only remaining grazers. The lack of excessive grazing pressure should facilitate the re-establishment of native grasses and forbs after treatments are implemented to reduce dominance of piñon and juniper trees.

Treatment Descriptions

Thinning Treatments

The post-settlement trees that were targeted for thinning ranged from one-year seedlings to 100-175 year old trees (Classes 1-3; Bradshaw and Reveal, 1943). Most post-settlement trees were <100 years old. A few widely scattered pre-settlement >175 year old trees (Class 4; Bradshaw and Reveal, 1943) were present on the site and were not targeted for thinning. Age classes were characterized by general characteristics such as diameter at stump height or breast height, total height, and growth form (Bradshaw and Reveal, 1943). We developed a classification scheme specific to our study site that was based on diameter at groundline and age as determined by core samples (J. Matchett unpublished data), using general guidelines from Bradshaw and Reveal (1943) and Miller et al. (1981) (Table 1).

Table 1. Groundline diameter classes used to distinguish age class for juniper and piñon trees. Breakpoint diameters based on Bradshaw and Reveal (1943) and Miller et al. (1981).

	Juniper		Piñon	
	diameter at groundline			
	----- *cm* -----	----- *in* -----	----- *cm* -----	----- *in* -----
Class 1	<10.2	<4	<8.9	<3.5
Class 2	10.2-24.1	4-9.5	8.9-21.8	3.5-8.6
Class 3	24.2-35.8	9.6-14.1	21.9-31.8	8.7-12.5
Class 4	>35.8	>14.1	>31.8	>12.5

The chain saw thinning treatments consisted of either a cut or a cut-limb-scatter. Trees were not marked prior to cutting, but rather the thinning crews were briefed on the characteristics that constitute a post settlement tree and were given the direction to cut four post settlement trees and leave the fifth post settlement tree they encountered uncut. In this manner, an approximately 80 percent reduction in tree density of each species should occur. In the cut treatment, trees were cut with either loping shears or chainsaws and left where they fell. The cutting methods were the same in the cut-limb-scatter treatment, but the larger trees were then limbed to manageable lengths and the material scattered across the site, avoiding placing slash under the driplines of uncut trees. Approximately 20 percent of the chain saw thinning was accomplished by a National Park Service fire crew with the remainder completed by contract crews.

The herbicide thinning treatment used 15 percent Tordon 22K (DOW) that was batch mixed at 11.4 liters (three gallons) increments directly into SP-3 backpack sprayers at a rate of 709.8 milliliters (24 fluid ounces) of chemical to 3.78 liters (1 gallon) of water with 29.6 milliliters (one fluid ounce) of Blaze-on blue dye and one milliliter (0.03 fluid ounce) of kinetic nonionic surfactant. Since this method is a spot treatment, the rate applied per unit area is dependent upon the target tree density. For this treatment, the average application was 1.84 liters

per hectare (25.15 ounces per acre) of Tordon 22K. The spray mixture was applied as a solid stream to the base of the tree at the soil interface (Williamson and Parker 1996). A 4.6m (15ft) buffer was left around each pre-settlement tree encountered due to concerns for chemical drift in the soil. Other trees, regardless of their classification that fell in this buffer zone, were not treated. It was estimated that these trees would constitute the 20% residual leave tree target; therefore, every post-settlement tree located outside the buffer zones was treated with herbicide to achieve the desired target of 80%. Herbicide application was performed by the Exotic Plant Management Team from Lake Mead Recreation Area.

Seeding Treatments

The seed mix consisted of bottlebrush squirreltail *(Elymus elymoides)* at 3 pounds per acre and blue grama *(Bouteloua gracilis)* at 2 pounds per acre, the two common perennial grasses at the study site. Seeding rates are based on pure live seed (PLS) content. Seeds were biotypes local to southern Utah and northern Arizona. Seeds were broadcast using handheld applicator equipment before the thinning treatments were applied. Treatment grids similar to those described for herbicide application were followed to ensure even seed application. No raking or other form of soil scarification was used so as to prevent disturbance of cultural resources in the area. Minimizing ground disturbance may also provide less potential habitat for weed species to invade the treatment sites. Weed seed germination and percent live seed testing was conducted by the seed company and the Lake Mead NRA nursery from batch samples provided prior to purchasing the bulk of the seed.

Thinning Experimental Design and Schedule

Study Design

Each of the 4 fuel treatments (including the control) were applied to 8 replicate treatment plots (n = 32 total). Each treatment plot was roughly 20 acres (8 ha, 200×400 m). Treatments were applied in the summer/fall of 2002 and 2003. The sampling unit for vegetation consisted of a 5×30 m Fire Monitoring Handbook (FMH) brush belt transect, and the sampling unit for fuels consisted of a 50m line transect which ran down the center of a 6 × 50m belt transect (see Sampling Methods below). Each of the 32 treatment plots had three sub-sampling units randomly located within them, such that the edge of each sampling unit was >30 m from the plot edge.

Sampling Schedule

Pre-Treatment (2002-2003)

5 × 30 meter brush belt transects

- Density of woody perennial plants
- Cover of woody perennial plants
- Density of herbaceous plants
- Cover of herbaceous plants

Post-Treatment Years 1 and 2 (2004-2005)

5 × 30 meter brush belt transects

- Density of woody perennial plants
- Cover of woody perennial plants
- Density of herbaceous plants
- Cover of herbaceous plants

- Seedbank density and diversity

20 × 50 meter modified-Whittaker plots

- Plant diversity

6 X 50 meter tree belt transects

- Density and status of trees by species

50 meter line intercept

- Cover of litter, slash, coarse and fine woody fuels, live and dead shrubs, grass, and forbs (late summer)

Thinning Plus Seeding Experimental Design and Schedule

Study Design

Each combination of the 2 thinning and 2 seeding treatments were applied to 10 replicate treatment plots (n=40 total). Treatment plots were 5 acres (2 ha, 142×142 m). Seeding treatments were applied in fall 2004, and thinning treatments were applied immediately thereafter. It was hoped that the surface disturbance inherent to thinning crews working on the plots would help integrate the seed into the soil. The sampling unit for vegetation consisted of five 1×1 m quadrats equally spaced along a 25 m transect, with 3 randomly-located transects within each treatment plot. Aerial cover (visually estimated) and density for each of the seeded species, shrubs, forbs, and trees were recorded in each quadrat.

Sampling Schedule

Vegetation sampling occurred once in summer of 2006 (2 years post-treatment)

Sampling Methods

FMH Brush Belt Transect

Density of woody perennial plants (trees, shrubs, and cacti) was measured in the brush-belt transect. Each individual having ≥50% of its rooted base within the belt transect was counted. Data were recorded by species and age class. Age class of each individual was identified as either dead, immature-seedling, resprout, or mature-adult. Density of live herbaceous plants was collected within ten 1-m^2 quadrats (five quadrats along each of the two 30-m sides of the brush belt transect).

The cover of vegetation, litter, and substrates (e.g. bare soil, rock, lichens, etc.) were measured by the point-intercept method A sampling rod was lowered at every 30 cm along each of the two 30-m transect lines (100 points per transect). The height at which each species touched the sampling rod was recorded.

Seedbank density and diversity were measured from soil subsamples taken adjacent to each of the four corners of the modified-Whittaker plot. Each subsample consisted of four soil cores (6 cm diameter × 3 cm deep; volume = 339 cm^3) which were pooled together. Soil seedbanks were assayed by growing them out in a greenhouse and counting the number of seedlings for each species. The methods were adapted from Brenchley and Warington (1939), later modified by Young and Evans (1975).

Modified-Whittaker Plot

Plant richness was measured at multiple scales (1, 10, 100, and 1,000 m^2) within a 20 × 50 m modified-Whittaker plot overlaid upon each brush-belt plot..

Fuelbed Measurements

Fuelbed measurements were quantified by evaluating the combination of sampling techniques described above (data on density and cover) as well as installing some fuel assessment transects. The sampling unit for fuels was a 50 m line transect which ran down the center of a 6 × 50 m belt transect. Fuel data was collected along the 50 m line transect using the line-point intercept method (Lutes and others 2006) and tree data was collected within the belt transect. Plots were established in 2004 after completion of the thinning treatments and measured in late August/early September of 2004 and 2005.

Trees

Since cutting took place before fuelbed plot establishment, we could not note the features such as tree height, growth form, or diameter at breast height or stump height of cut trees that Bradshaw and Reveal (1943) used for their classification system and that the thinning crew used when making the decision of which trees to cut. We used data from Miller et al (1981) to develop relationships between diameter at stump height, diameter at breast height, and groundline diameter (g.l.d.) and we assigned each of the trees/stumps in our data set a Class based solely on g.l.d. (Table 1). Trees that were treated with herbicide were either labeled as dead or "sick." If, by appearance, they were unhealthy and expected to die in the near future they were deemed sick.

All trees/stumps with more than 50% of their basal area located within the 6 × 50 m belt transect that had a g.l.d. of 7.6cm (3 in.) or greater were recorded along with the species. This left the smallest Class 1 trees unmeasured, leading to the assumption that the Class 1 trees measured and those that were thinned were representative of smaller trees as well. Although other tree attributes were measured, density and percent reduction will be the only tree data presented in this paper.

Surface fuels

Along the 50m line transect that bisected the belt transect, we sampled fuel groups by category (fine slash, coarse slash, fine woody debris, coarse woody debris, grass, live shrubs, dead shrubs, trees by species, forbs, and bare soil) using the line-point intercept sampling methods. The height of the tallest interception by fuel group was recorded at 0.5m intervals. Since we did not sample prior to treatment establishment, the distinction between 'slash' and 'debris' was made in an attempt to determine woody fuel presence prior to and following treatment application. True shrubs such as scrub oak (*Quercus turbinella*), cliffrose (*Purshia mexicana*) and sagebrush (*Artemisia tridentata*) as well as suffrutescent plants such as broom snakeweed (*Gutierrezia sarothrae*) were combined in our 'live shrub' and 'dead shrub' categories. Live shrubs were those where any portion of the stem was determined to be living. The fuels that contribute to fire spread in this system are made up of plants such as shrubs and grasses as much as it is woody fuels; therefore, much of our focus was spent on assessing continuity of plant growth.

Statistical Analyses

Preliminary data analyses were performed using generalized linear mixed models (the SAS GLIMMIX and MIXED procedures). Predictor variables (fixed effects) for the thinning experiment consisted of the 4 thinning treatments (cut; cut, limb, scatter; chemical; untreated control) and year. Because our sampling design included three subsamples within each larger treatment plot, a random plot effect was included in each model to take into account within-plot covariance and avoid pseudo-replication. Predictor variables for the thinning plus seeding experiment consisted of the 2 thinning treatments (cut, limb, scatter; untreated control) and 2 seeding treatments (seed; unseeded control). Response variables included vegetation cover, density, and richness. Data were analyzed by individual species or were grouped into various categories of interest (such as native annual forbs, shrubs and trees, etc.). Because the response data is multivariate in nature, future statistical analyses will apply multivariate techniques such as ordination and structural equation models. All significance levels were seat at the 0.05 level.

PRELIMINARY RESULTS

Thinning Experiment

- Prior to treatments there were no statistical differences found in density of either juniper or piñon pine among plots assigned to the different treatment types.
- Thinning treatments differed in their costs: $400/acre (cut), $500/acre (cut, limb, scatter), and $70/acre (herbicide)
- Thinning treatments reduced densities of juniper by an average of 83% (cut), 92% (cut, limb, scatter), and 68% (herbicide).
- Thinning treatments reduced densities of piñon pine by an average of 77% (cut), 64% (cut, limb, scatter), and 77% (herbicide).

- All thinning treatments caused an immediate increase in understory forb cover (Table 2, Fig. 1)

Table 2. ANOVA results for forb cover.

Effect	Num DF	Den DF	F Value	P value
Thinning	3	27.61	4.48	0.0110
Year	1	144.5	676.16	<.0001
Thinning x Year	3	144.5	0.70	0.5544

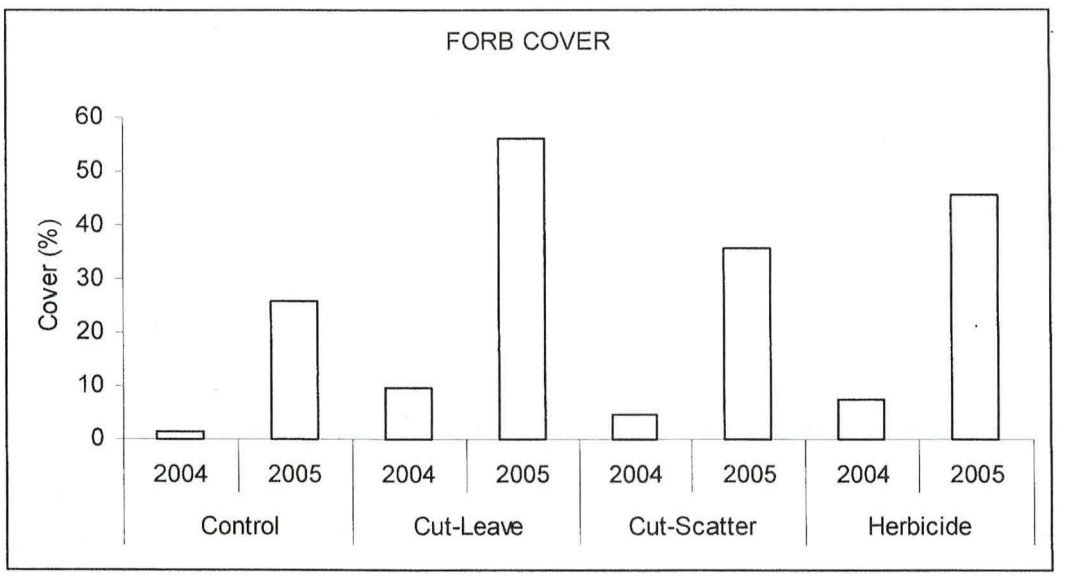

Fig. 1. Response of forb cover to thinning treatments.

- Shrub density increased in the cut-scatter and herbicide treatments beginning in 2004, the first post-treatment year, indicating that those thinning treatments have stimulated shrub recruitment (Table 3, Fig. 2).

Table 3. ANOVA results for shrub density.

Effect	Num DF	Den DF	F Value	P value
Thinning	3	28.46	3.24	0.0368
Year	1	146.5	1.57	0.2122
Thinning x Year	3	146.4	1.21	0.3097

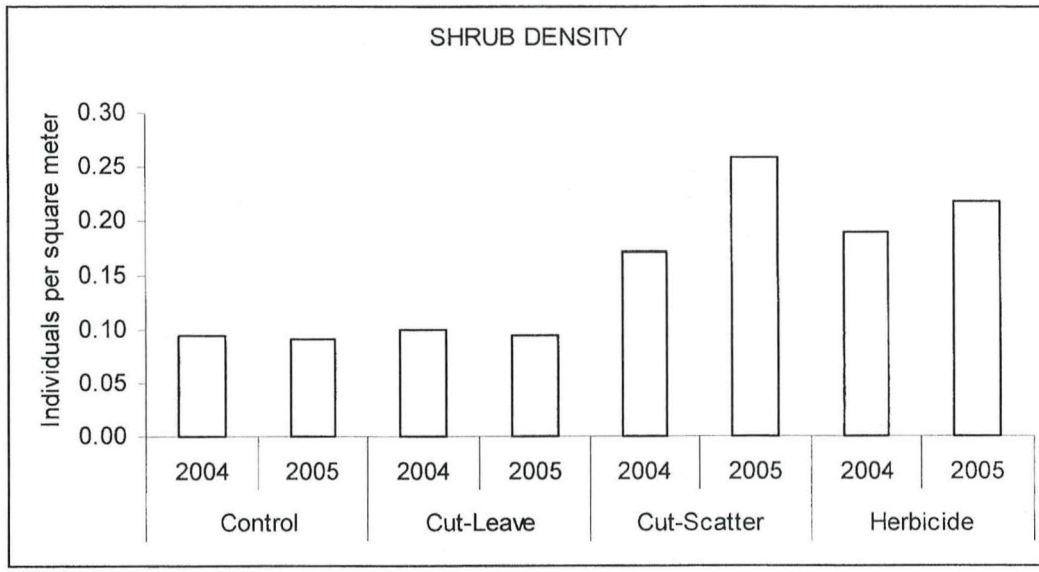

Fig. 2. Response of shrub density to thinning treatments.

- All thinning treatments increased species richness, especially at larger spatial scales (e.g. 100 and 1,000 m^2) by 2005, the second post-treatment year (Table 4, Fig. 3)

Table 4. ANOVA results for species richness.

Effect	Num DF	Den DF	F Value	P value
Thinning	3	159.7	10.09	<.0001
Year	1	700	156.56	<.0001
Thinning x Year	3	700	2.73	0.0430
Area	1	635.7	6188.72	<.0001
Area x Thinning	3	636.6	2.69	0.0455
Area x Year	1	700	2.06	0.1517
Area x Thinning x Year	3	700	0.02	0.9953

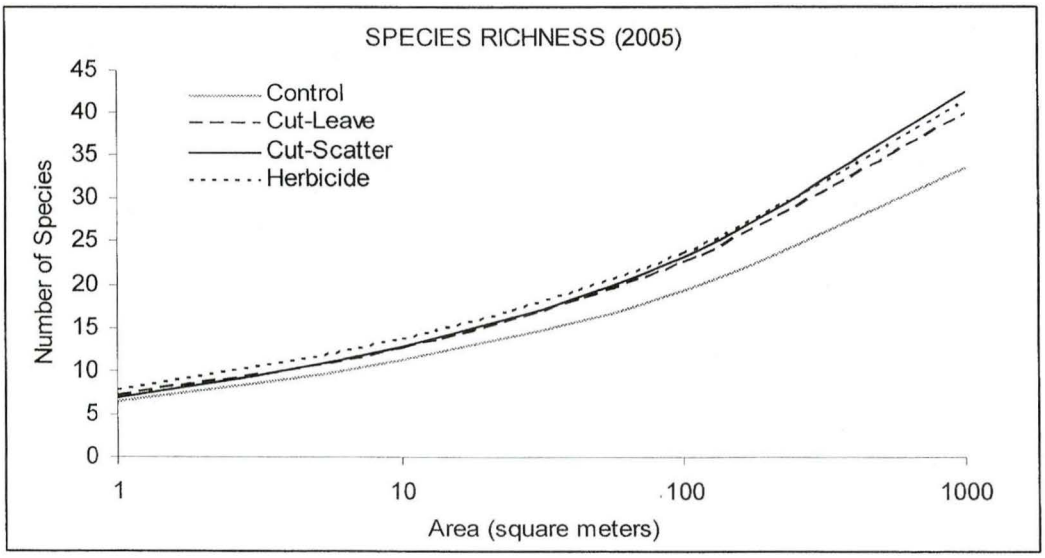

Fig. 3. Response of plant species richness to thinning treatments in 2005.

- Live shrubby fuels increased in response to thinning by 2005, the second post-treatment year (Fig. 4). These data include cover of true shrubs, suffrutescent shrubs, and *Cordylanthus* species.

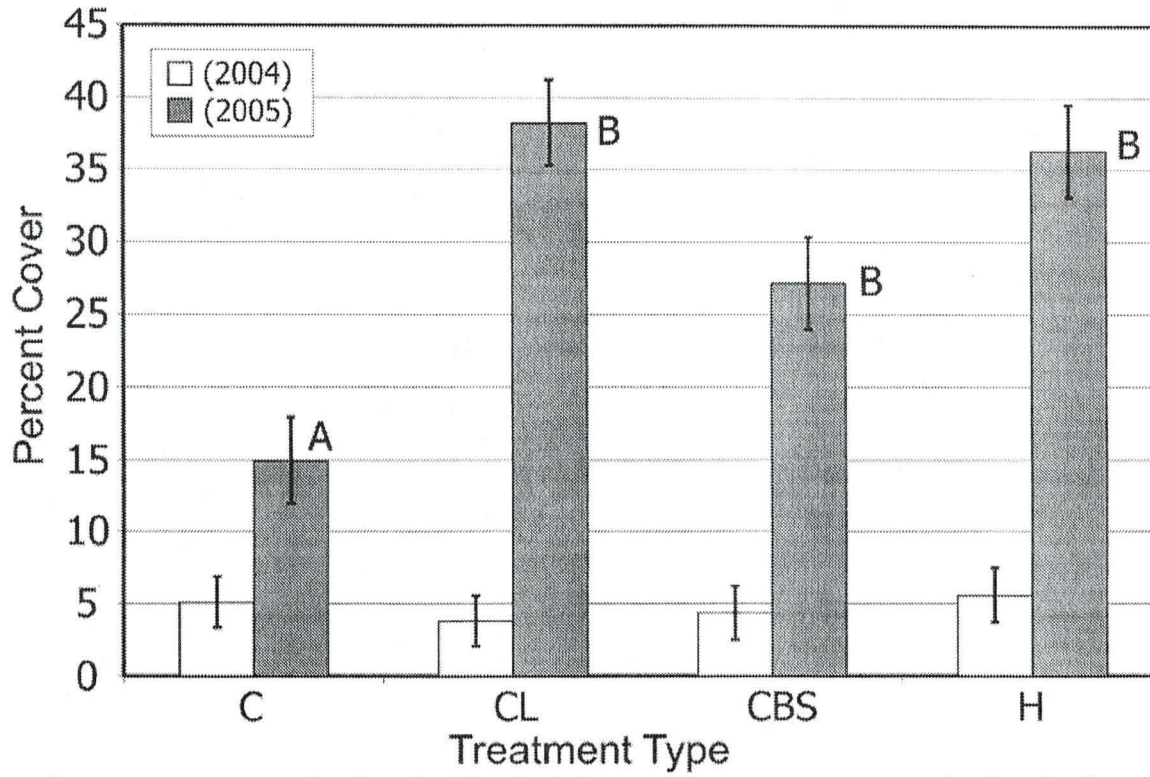

Fig. 4. Percent cover for live shrubby fuels by treatment type as measured using the line-point intercept sampling method +/-1SE. There were no significant differences between types in 2004 ($F_{3,26} = 0.19$; $p = 0.9051$) Uppercase letters (A, B) represent significant differences between types in 2005 ($F_{3,26} = 12.29$; $p < 0.0001$). C = control, CL = cut-leave, CBS = cut-buck-scatter, and H = herbicide. (reprinted from Smith et al. 2006).

- There were no significant differences between treatment types within a given year for dead shrub cover (Fig. 5). However, percent cover of dead shrubs generally increased between the first and second year in all treatments, especially the herbicide treatment.

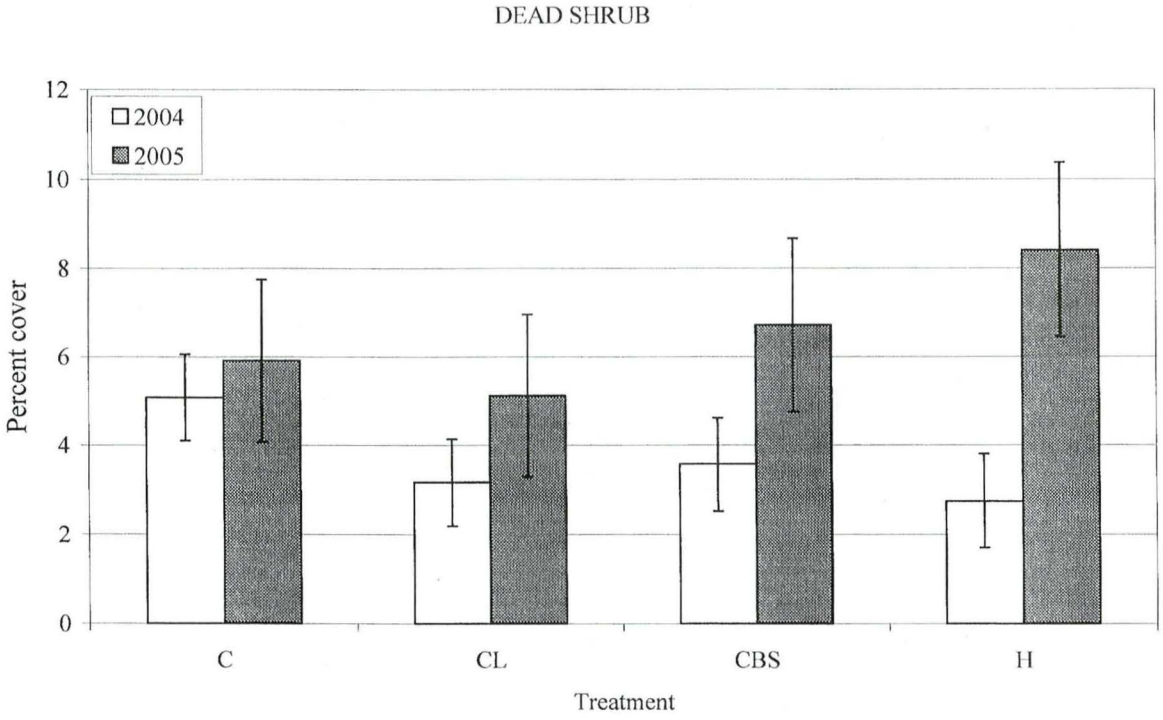

Fig. 5. Percent cover of dead shrubs by year and treatment. There were no significant differences seen between treatment types within a year ($F_{3,26} = 0.3887$ and $F_{3,26} = 0.6580$)

- There were no significant differences in litter/duff cover between treatment types (Fig. 6)

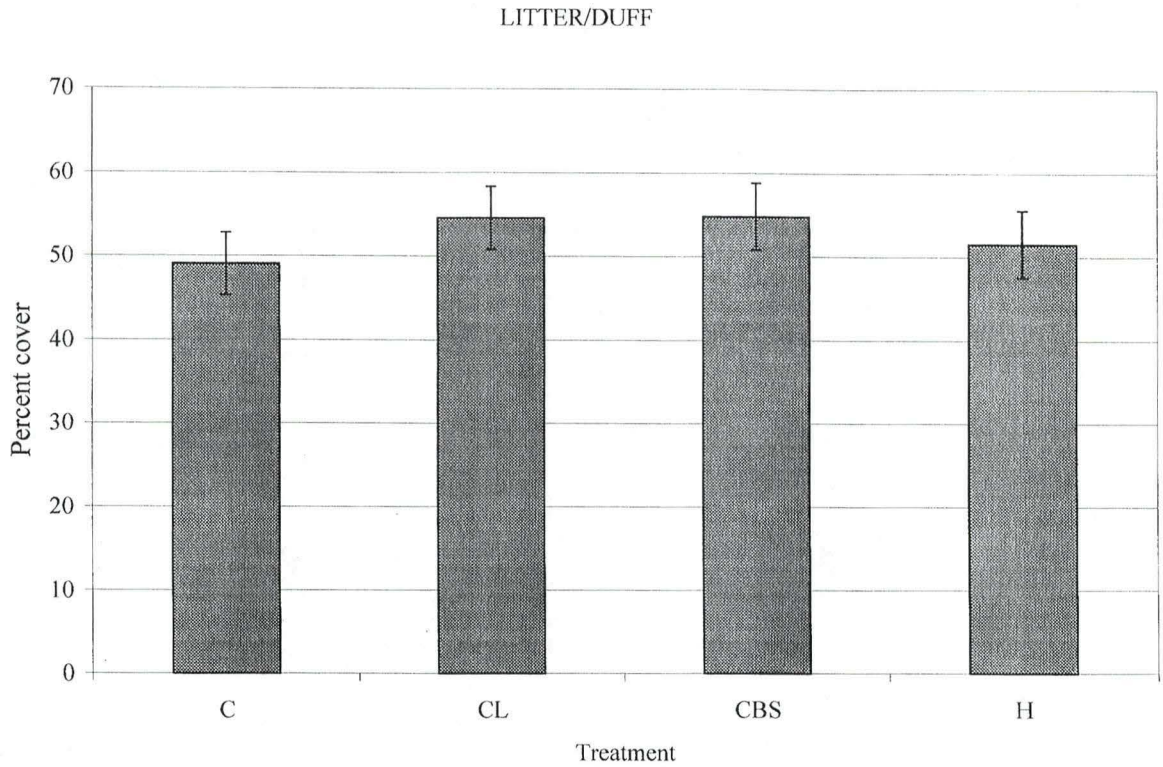

Fig. 6. Percent cover of litter/duff by treatment. There were no significant differences seen between treatment types ($F_{3,26} = 0.6760$)

- Coarse woody fuel loads were significantly higher in the two chainsaw treatments compared to the control or herbicide treatments. (Fig. 7)

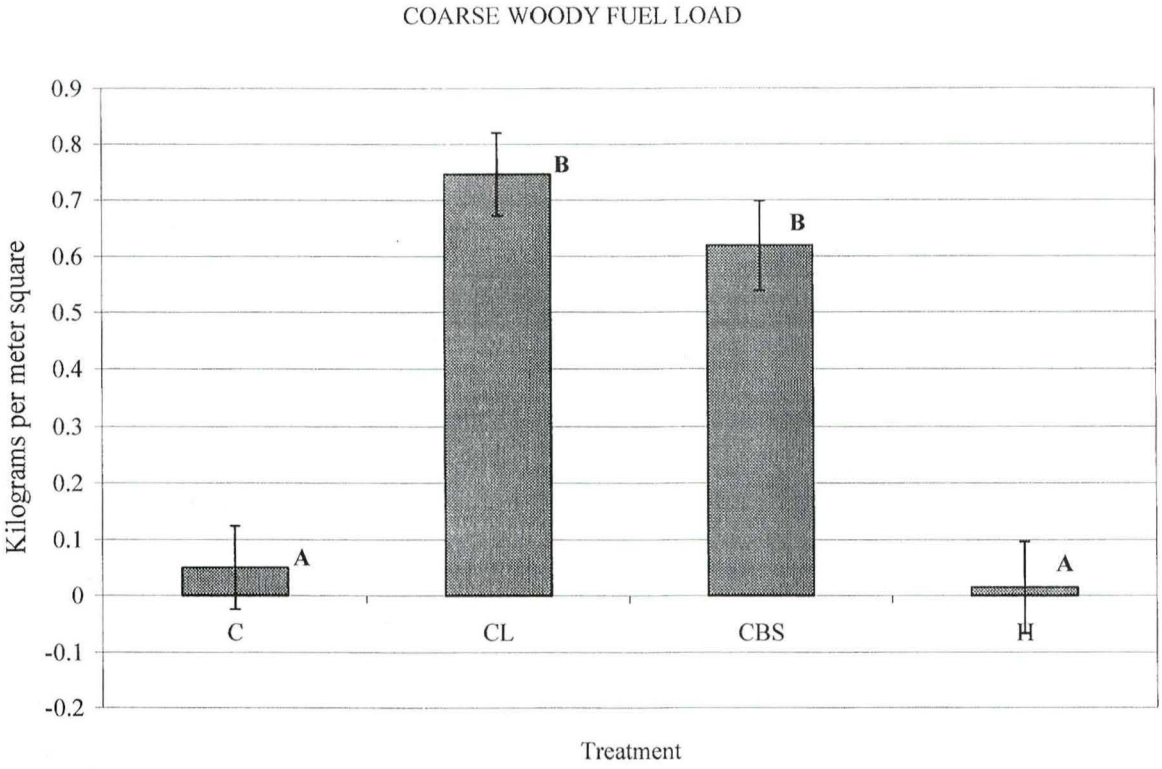

Fig. 7. Coarse woody fuel load by treatment type. The cut-leave and cut-back-scatter chainsaw treatments were the same statistically as were the control and herbicide treatments. Statistically, the chainsaw thinning treatments had higher fuel load than the control and herbicide treatments ($F_{3,26} = 0.0002$)

- Seedbank data are currently being analyzed. No results to report at the time of this report.

Thinning and Seeding Experiment

- Data are currently being analyzed. No results to report at the time of this report.

DELIVERABLES LISTED IN THE ORIGINAL PROPOSAL
(*summary of actual deliverable in italics*)

- Annual progress reports delivered at the Joint Fire Science PI workshop.

  Progress reports were delivered at the end of FY04 and FY05

- Integration of results into agency training workshops that the PIs participate in. For example, the NPS "Integrated Fire and Resource Management Planning" course the lead PI helped instruct recently at the Albright Training Center, Grand Canyon.

  Results and recommendations from this project were integrated into the following training courses:

  Fire in Ecosystem Management course at the BLM National Advanced Fire and Resource Institute, Tucson AZ (2004, 2005, 2006)

  Federal 401 Certification Program for Fire Management Personnel, Ecology module and Applied Biological Concepts in Land Management module, University of Nevada, Las Vegas (2006)

  Resource Advisor training for NPS and BLM desert fire managers. Laughlin NV (2006)

- A field tour of the site for land managers and other interested parties.

  A field tour is planned for summer 2007, after all post-treatment data (2004-2006) have been analyzed and final results from the project have been summarized.

- Website to provide information on the study plan, progress reports, and other deliverables for this project.

  Website established in 2004, and available at www.werc.usgs.gov/fire/lv/pj/lakemead

- Direct informal information transfer facilitated through close collaboration with management partners.

  Regular communication of results and discussions about additional information needs with staff associated with the following federal agency management units:

  Arizona Strip Field Office (BLM, AZ)
  Bishop Field Office, (BLM, CA)
  Ely Field Office (BLM, NV)
  Grand Canyon – Parashant National Monument (BLM and NPS, AZ)
  Las Vegas Field Office (BLM, NV)
  St. George Field Office (BLM, UT)
  Lake Mead National Recreation Area (NPS, NV)
  Spring Mountains National Recreation Area (USFS, NV)

- Presentation of results at the Biennial Conference of Research on the Colorado Plateau, and other scientific meetings.

Brooks, M.L. 2003. Effects of plant invasions on fire regimes. 2nd International Fire Ecology and Fire Management Congress, 16-20 November, 2003. Orlando, FL .

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Brooks, M.L. 2005. Evaluating effects of fuels treatments in arid and semiarid ecosystems. 4th USGS Wildland Fire Science Workshop. 8 December, Tucson, AZ.

Brooks, M.L., J.R. Matchett, C. Deuser, H. Smith, and H. Bastian. 2005. Comparison of thinning techniques for piñon-juniper encroached shrublands on the Shivwits Plateau, Arizona. National Fire Plan Workshop, 15-17 February, Albuquerque, NM.

Matchett, JR., C. Deuser, M. Brooks, and H. Smith. 2006. Comparison of thinning techniques for piñon-juniper encroached shrublands on the Shivwits Plateau, Arizona. Biennial Colorado Plateau Research Symposium. 8 November, Flagstaff, AZ.

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- Peer-reviewed journal articles and fact sheets.

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Brooks, M.L. et al. In preparation. Soil seedbank responses to piñon and juniper thinning on the western Coloroado Plateau.

Brooks, M.L. et al. In preparation. Vegetation and fuelbed responses to piñon and juniper thinning on the western Colorado Plateau. USGS, Western Ecological Research Center, Fact Sheet.

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